Efficiency and Renewables on the Grid: Getting to Significance

Presented to Edison Electric Institute

September 6, 2007

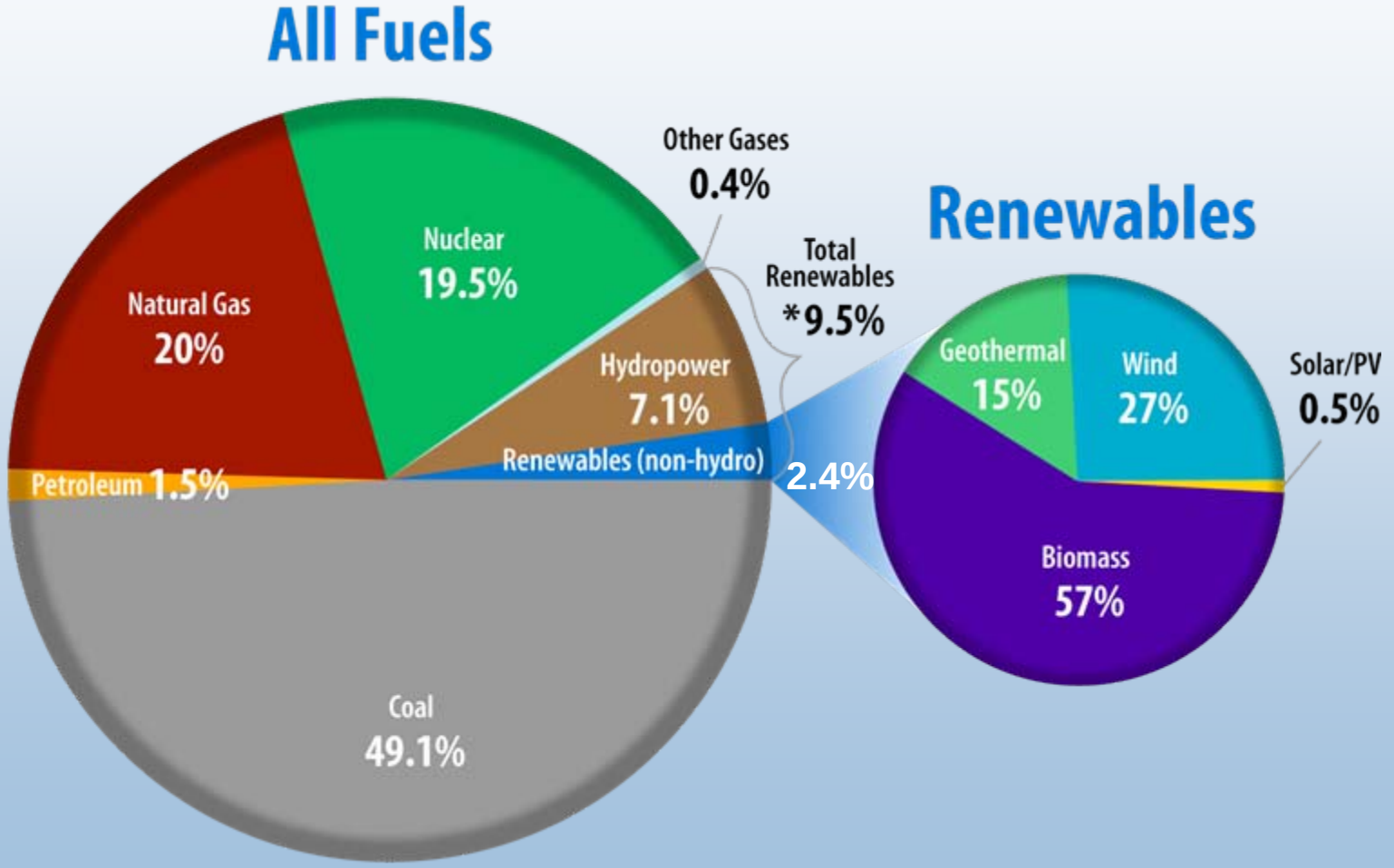
Dr. Dan E. Arvizu
Director, National Renewable Energy Laboratory

Two Key Questions

- Are energy efficiency and renewable energy technologies poised to have a significant impact?
- Must policy measures include a correspondingly aggressive investment in technology innovation and cost reduction?

What Are the Major Renewables?

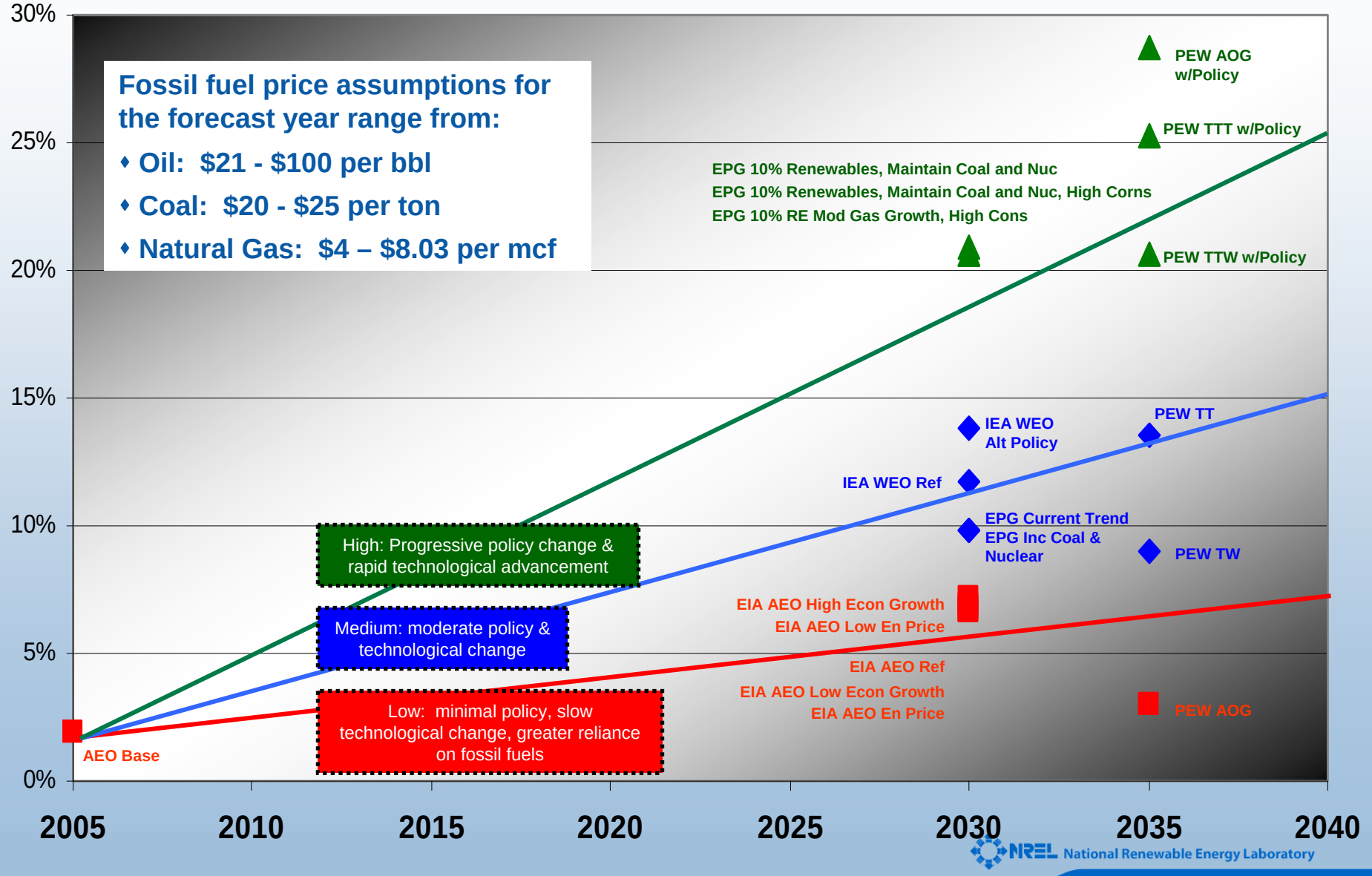
Electricity Net Generation – 2006



* Source: EIA Annual Energy Review 2007

U.S. Renewable Energy Contributions

Percent of Total Electric Generating Capacity



We Are Now Setting Aspirational National Goals – Setting the Bar Higher

U.S. national goals

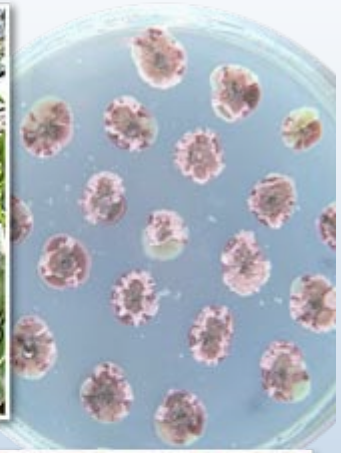
- Biofuels: reduce gasoline usage by 20% in ten years
- Wind: 20% of total provided energy by 2030
- Solar: Be market competitive by 2015 for PV and 2020 for CSP

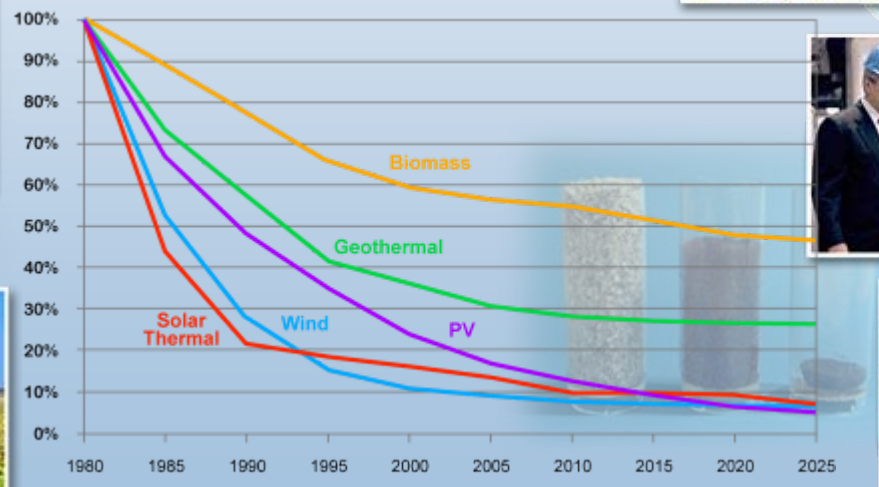
Getting to “Significance” Involves…

Source: NREL

Are energy efficiency and renewable energy technologies poised to have a significant impact?

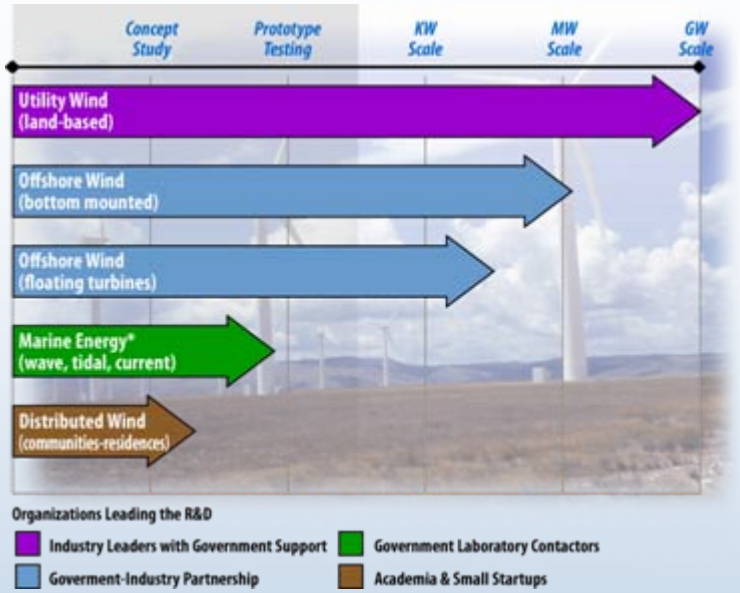
Past Investments Have Yielded Impressive Cost Reductions



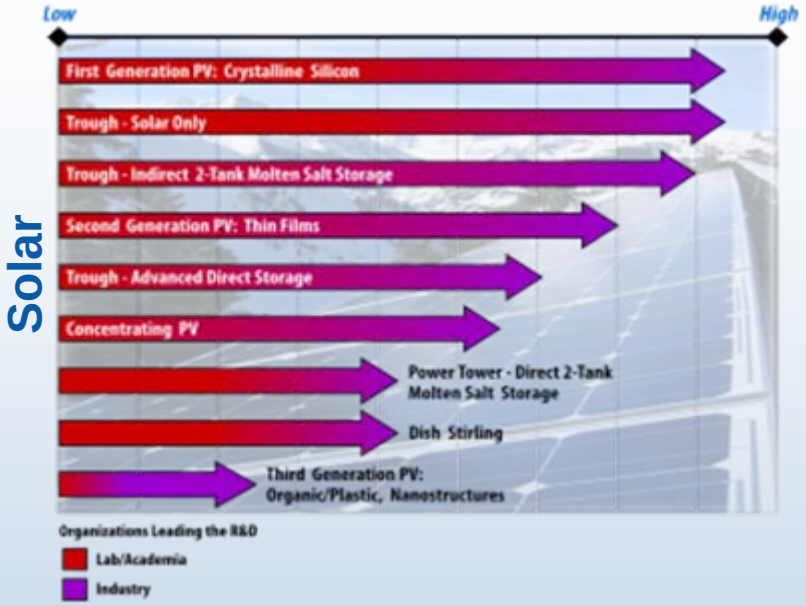


Technology Options Are Evolving

Wind



Solar



Geothermal

Wind

Today's Status in U.S.

- 11,603 MW installed at end of 2006
- Cost 6-9¢/kWh at good wind sites*

DOE Cost Goals

- 3.6¢/kWh, onshore at low wind sites by 2012
- 7¢/kWh, offshore in shallow water by 2014

Long Term Potential

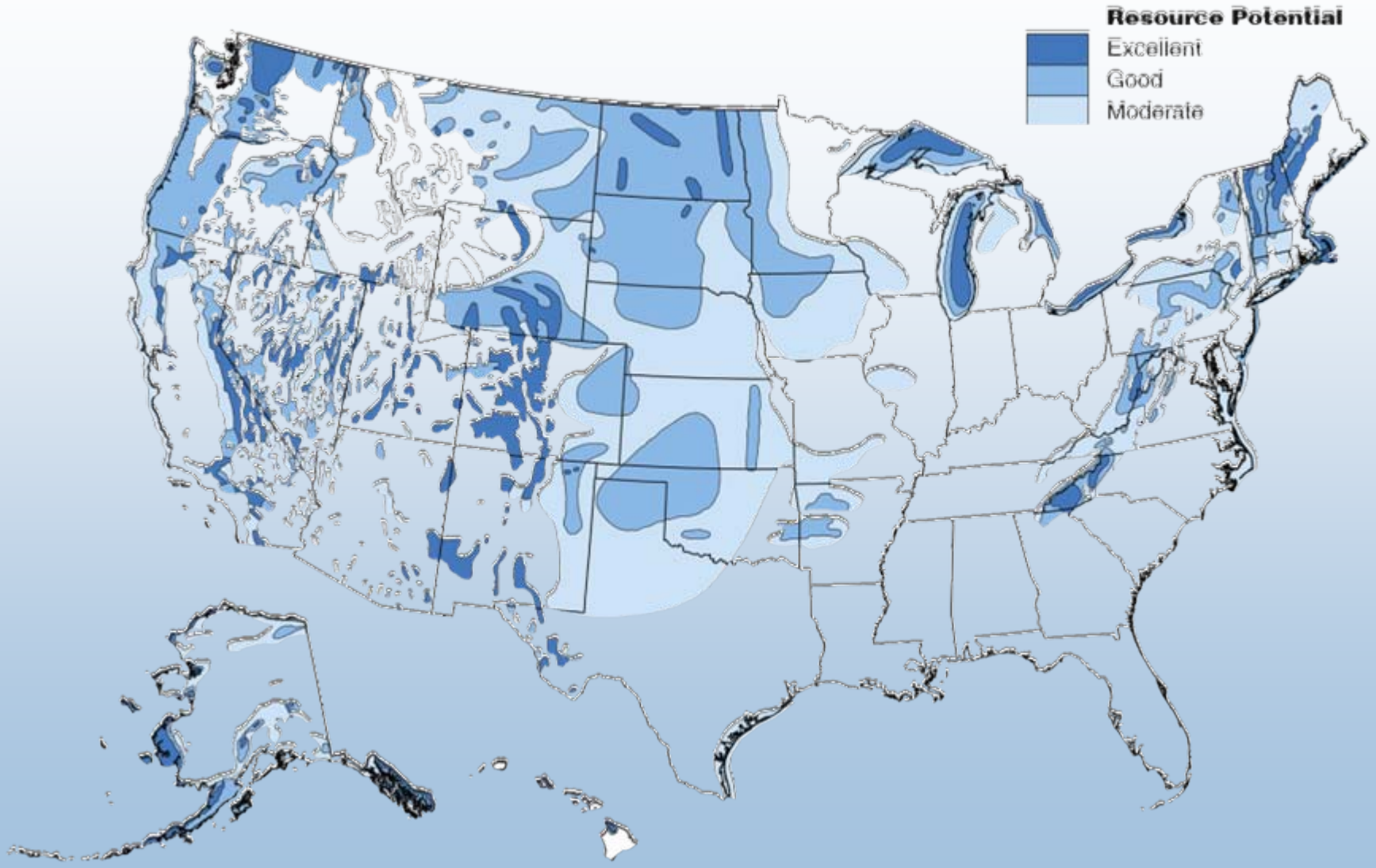
- 20% of the nation's electricity supply

NREL Research Thrusts

- Improved turbine performance and reliability
- Distributed wind technology
- Drivetrain reliability
- Utility grid integration

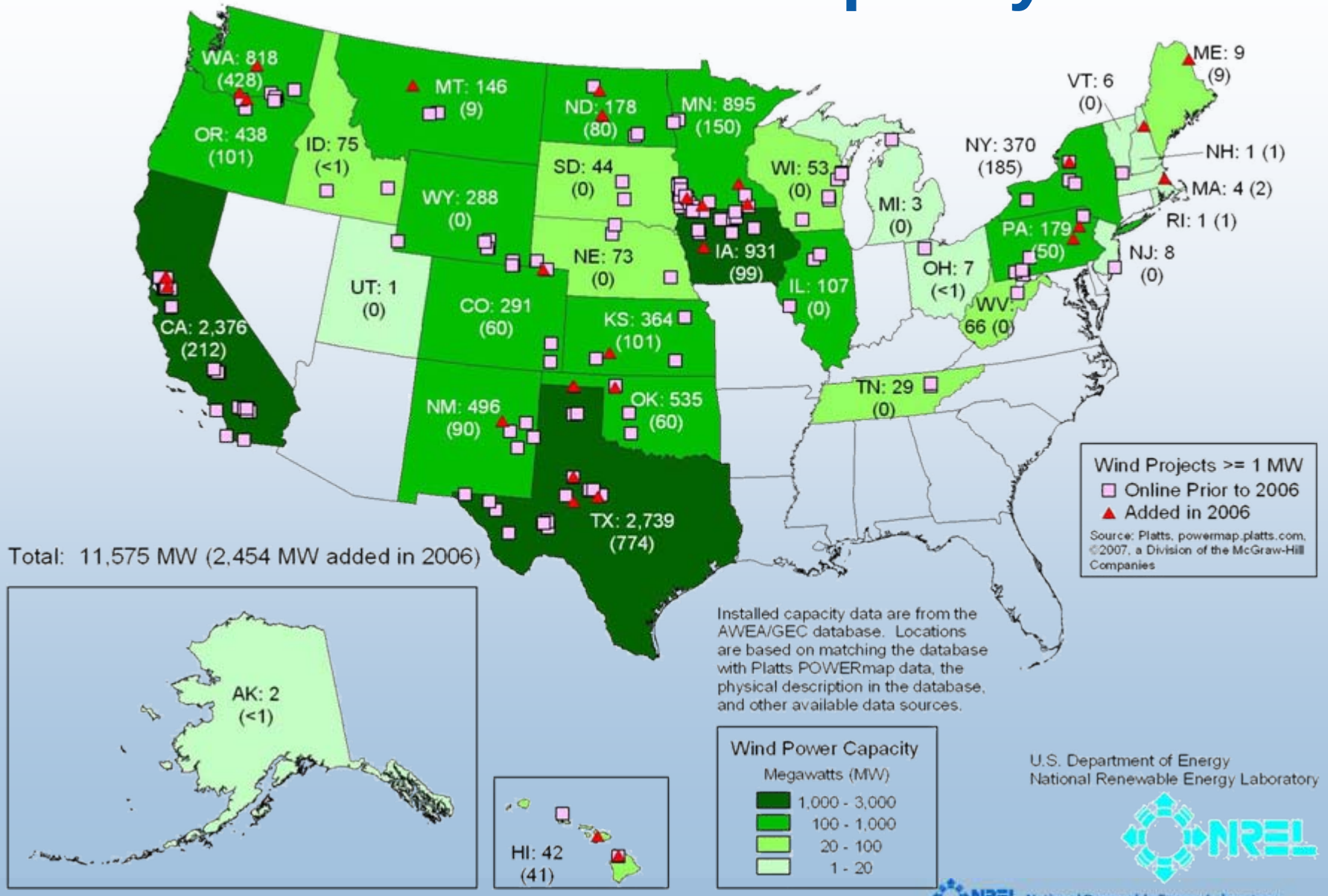
* With no Production Tax Credit
Updated 1/07, validated 7/07
Source: U.S. Department of Energy, American Wind Energy Association

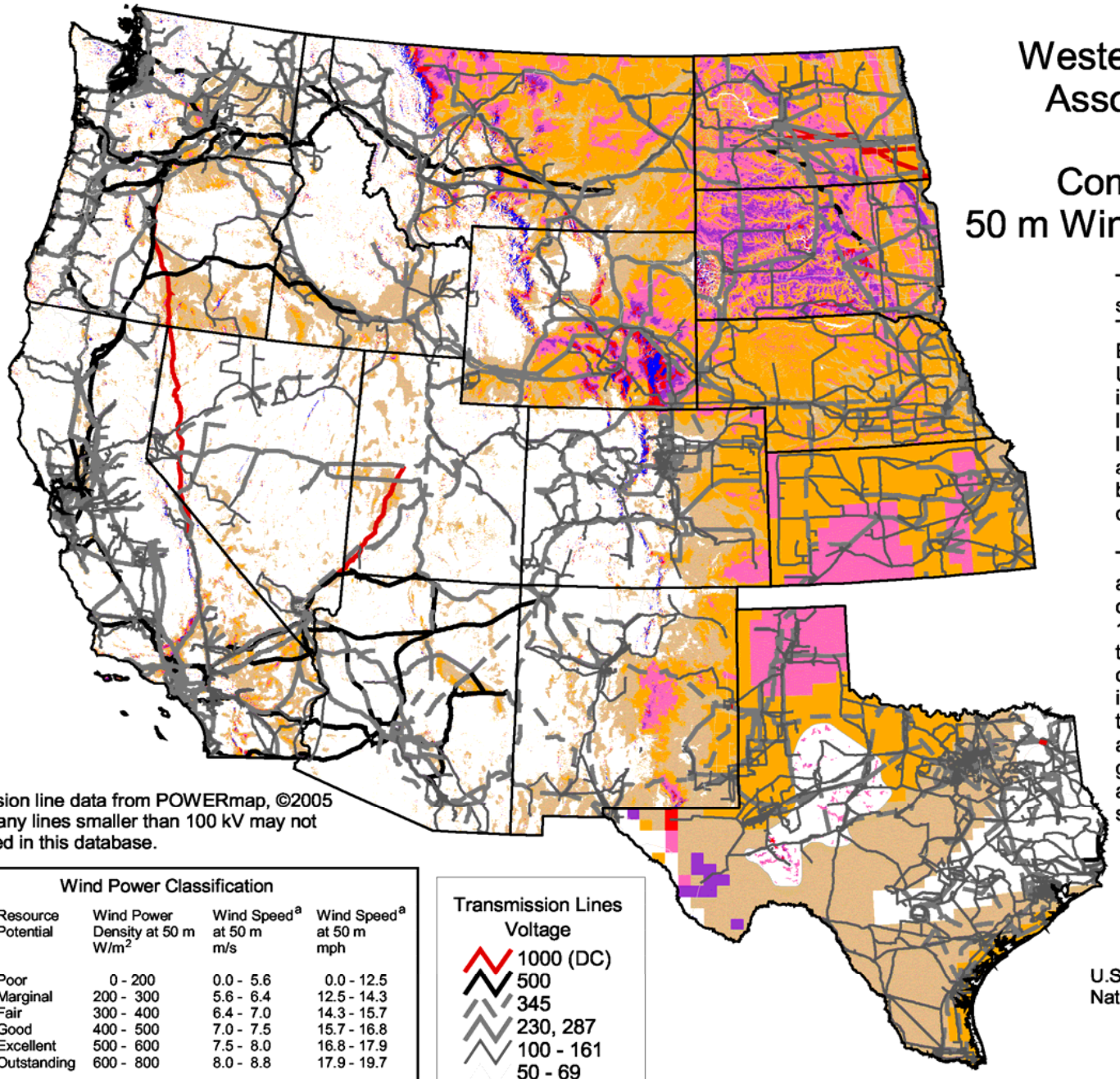
Wind Resources



Source: U.S. Department of Energy Wind Resource Atlas of the United States (1987)

Installed Wind Capacity





Western Governor's Association Area

Combined Data
50 m Wind Resource Data

The wind resource information shown for Kansas and most of Texas is from the 1987 "Wind Energy Resource Atlas of the United States". Wind resource is shown for every 1/3 degree of longitude by 1/4 degree of latitude. As little as 5% of the area shown in each area may be well-exposed to the power class displayed.

The remaining wind resource assessments were conducted on a state-by-state basis from 1999 to 2004. Over that time, the methodology and resolution of the data varied due to changes in the assessment process. Also, the fine resolution of these assessments may prevent many good resource areas from appearing when viewed at this scale.

Transmission line data from POWERmap, ©2005 Platts. Many lines smaller than 100 kV may not be included in this database.

Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
1	Poor	0 - 200	0.0 - 5.6	0.0 - 12.5
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7

[a] Wind speeds are based on a Weibull k value of 2.0

Transmission Lines
Voltage

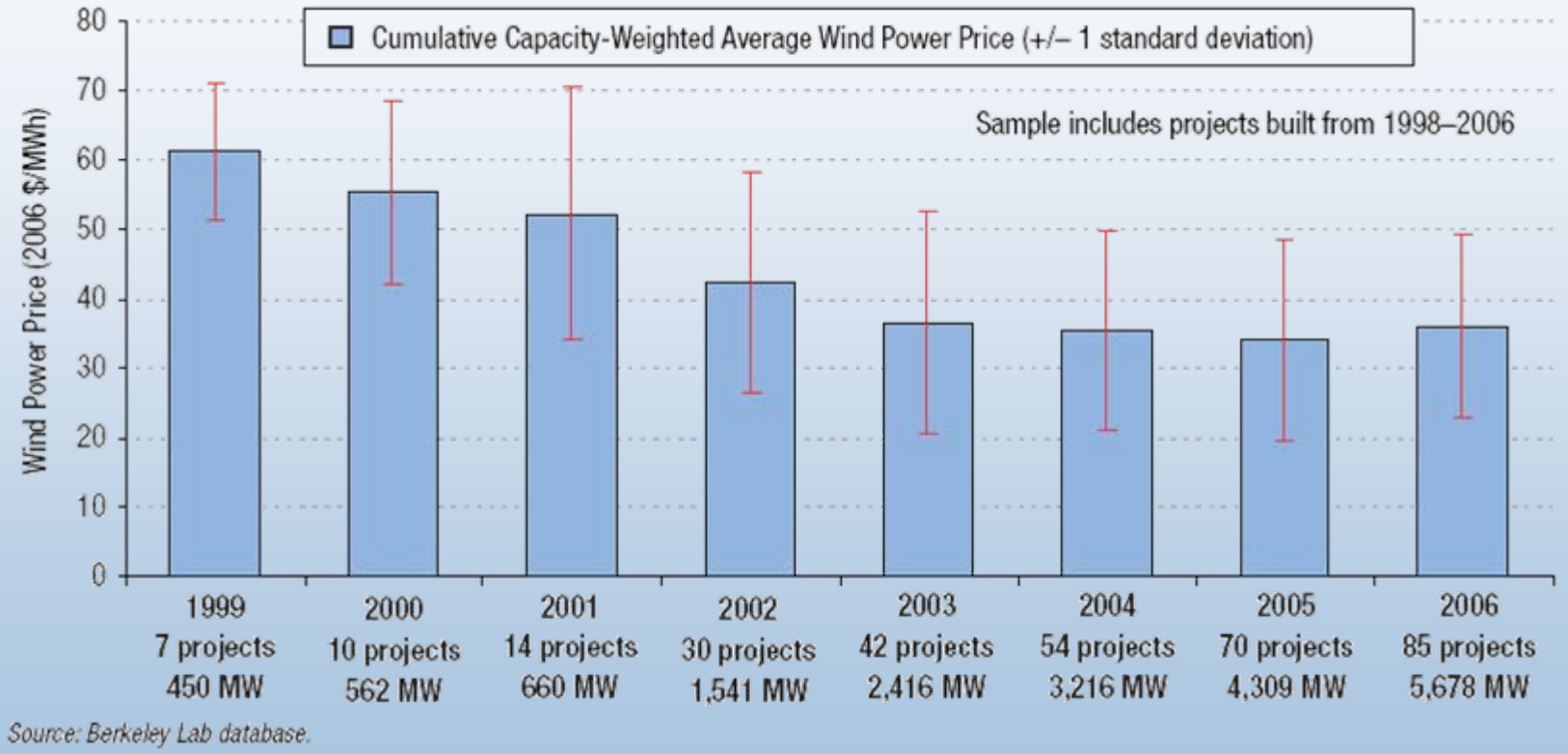
- 1000 (DC)
- 500
- 345
- 230, 287
- 100 - 161
- 50 - 69

U.S. Department of Energy
National Renewable Energy Laboratory

NREL

11-JUL-2005 5.3.7

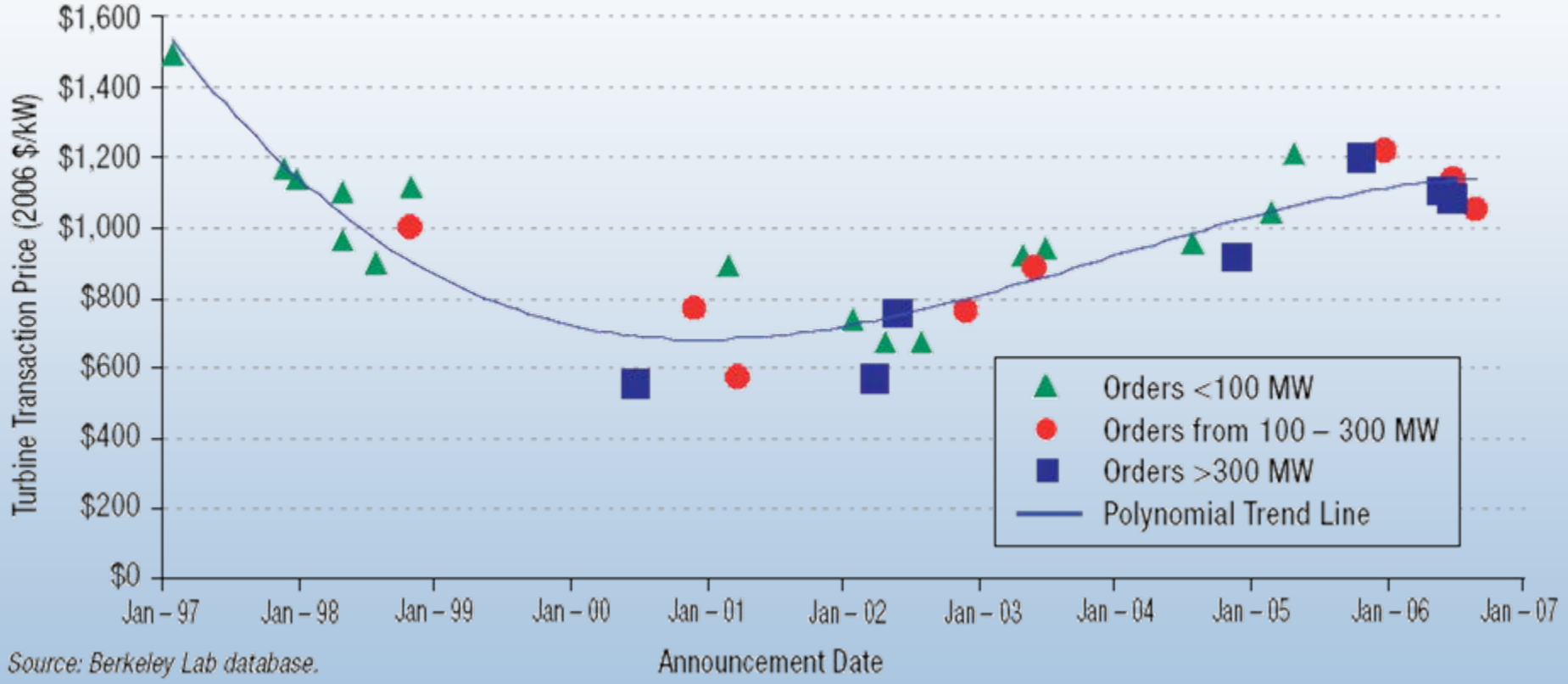
Wind Power Prices Are Up in 2006



Source: Berkeley Lab database.

Cumulative Capacity-Weighted Average Wind Power Price Over Time

Project Cost Increases Are a Function of Turbine Prices



Reported U.S. Wind-Turbine Transaction Prices Over Time

Integrating Wind Into Power Systems

New studies find integrating wind into power systems is manageable, but not costless

Date	Study	Wind Capacity Penetration	Cost ($/MWh)				
			Regulation	Load Following	Unit Commitment	Gas Supply	TOTAL
2003	Xcel-UWIG	3.5%	0	0.41	1.44	na	1.85
2003	We Energies	4%	1.12	0.09	0.69	na	1.90
2003	We Energies	29%	1.02	0.15	1.75	na	2.92
2004	Xcel-MNDOC	15%	0.23	na	4.37	na	4.60
2005	PacifiCorp	20%	0	1.6	3	na	4.60
2006	CA RPS (multi-year)	4%	0.45*	trace	na	na	0.45
2006	Xcel-PSCo	10%	0.2	na	2.26	1.26	3.72
2006	Xcel-PSCo	15%	0.2	na	3.32	1.45	4.97
2006	MN-MISO 20%	31%	na	na	na	na	4.41**

* *3-year average* ** *highest over 3-year evaluation period*

Key Results from Major Wind Integration Studies Completed 2003-2006

Some Additional Reserves May Need to be Committed

Reserve Category	Base		15% Wind		20% Wind		25% Wind	
	MW	%	MW	%	MW	%	MW	%
Regulating	137	0.65%	149	0.71%	153	0.73%	157	0.75%
Spinning	330	1.57%	330	1.57%	330	1.57%	330	1.57%
Non-Spin	330	1.57%	330	1.57%	330	1.57%	330	1.57%
Load Following	100	0.48%	110	0.52%	114	0.54%	124	0.59%
Operating Reserve Margin	152	0.73%	310	1.48%	408	1.94%	538	2.56%
Total Operating Reserves	**1049**	**5.00%**	**1229**	**5.86%**	**1335**	**6.36%**	**1479**	**7.05%**

Source MN DOC

Estimated Operating Reserve Requirement for MN BAs – 2020 Load

Solar

Photovoltaics and Concentrating Solar Power

Status in U.S.

PV
- 565 MW
- Cost 18-23¢/kWh

CSP
- 420 MW
- Cost 12¢/kWh

Potential:

PV
- 11-18¢/kWh by 2010
- 5-10 ¢/kWh by 2015

CSP
8.5¢/kWh by 2010
5-7¢/kWh by 2020

Source: U.S. Department of Energy, IEA, Solar Energy Technologies Program Multi-Year Plan 2007

Updated July 2007

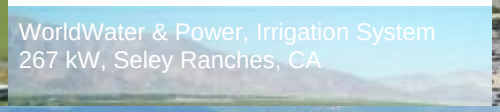
NREL Research Thrusts:

PV
- Partnering with industry
- Higher efficiency devices
- New nanomaterials applications
- Advanced manufacturing techniques

CSP
- Next generation solar collectors
- High performance storage

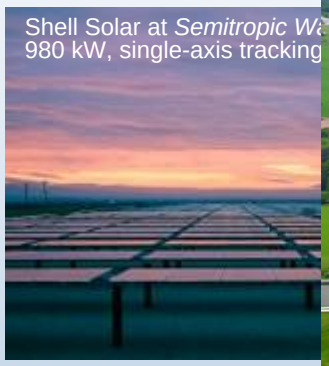
Moving Toward Our Destination


Ridge
Vineyards
PV Rooftop
65 kW, CA


WorldWater & Power, Irrigation System
267 kW, Seley Ranches, CA


RWE Schott Stillwell Avenue Subway Station, PV Canopy Roof, 250,000 kWh/yr, Brooklyn, NY


Powerlight, Bavarian community
6.750 MW, single-axis tracking
Mühlhausen, Germany


Shell Solar at *Semitropic Wa*
980 kW, single-axis tracking


er & Geothermal Energy Co.
stewater Plant, 622 kW,
CA


PowerLight PowerGuard
536 kW, Toyota Motor C


op system,

Alamosa PV Plant – Commercial Operation Testing

8 MW PV Plant – Phase 1 (3 MW)

Buildings

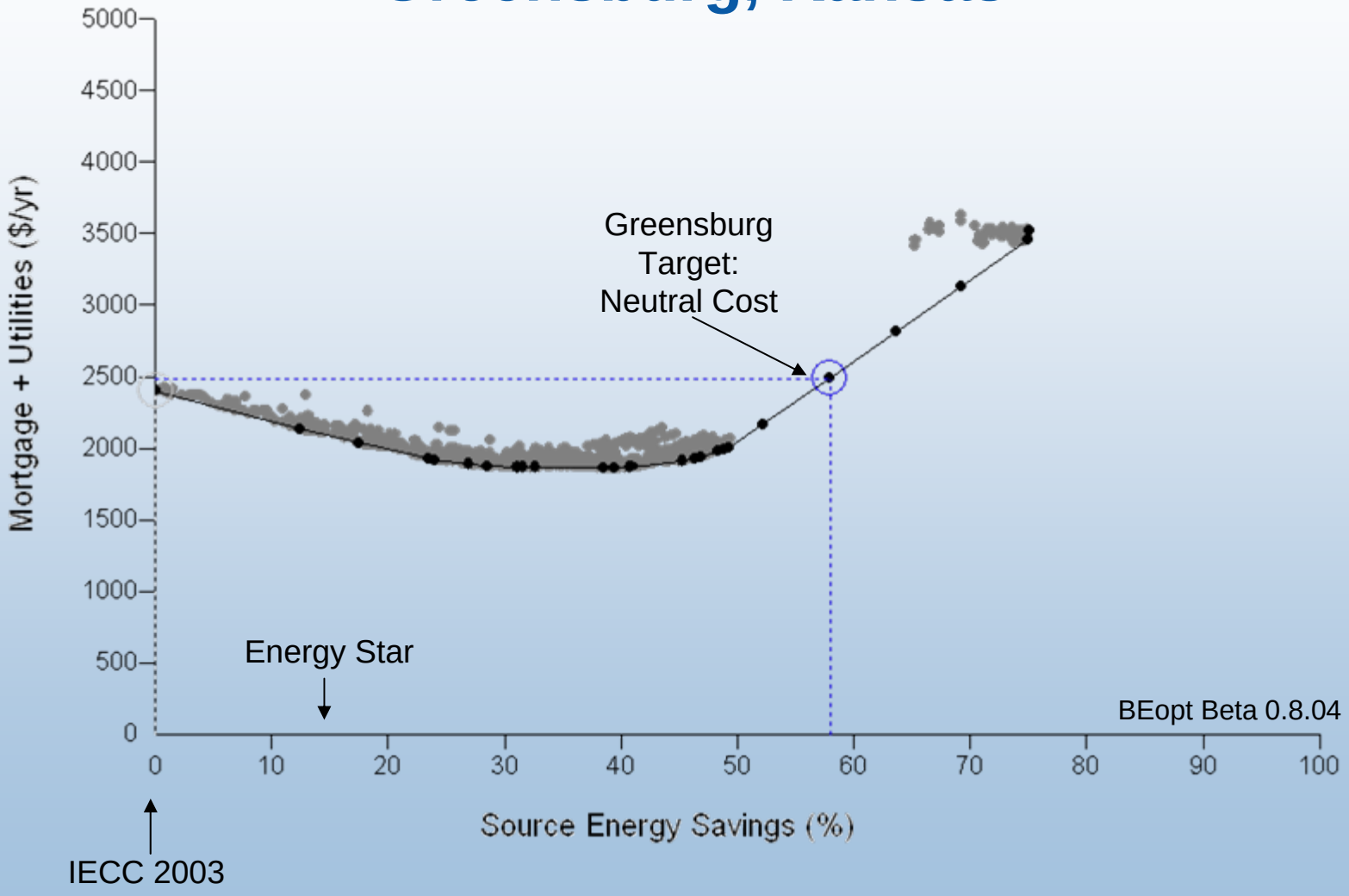
Status U.S. Buildings:
- 39% of primary energy
- 71% of electricity
- 38% of carbon emissions

DOE Goal:
- Cost effective, marketable zero energy buildings by 2025
- Value of energy savings exceeds cost of energy features on a cash flow basis

NREL Research Thrusts
- Whole building systems integration of efficiency and renewable features
- Computerized building energy optimization tools
- Building integrated PV

Updated June 2007

Neutral Cost Point Example
Greensburg, Kansas



(2000 ft2, 2-story, 16% window to floor area ratio, unconditioned basement)

Hydrogen

Status

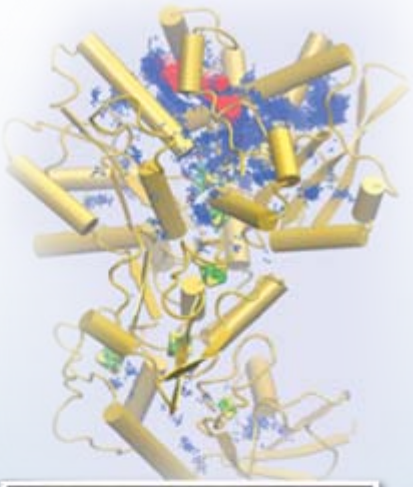
- Working with industry to develop technologies in quantities large enough, and at costs low enough, to compete with traditional energy sources.

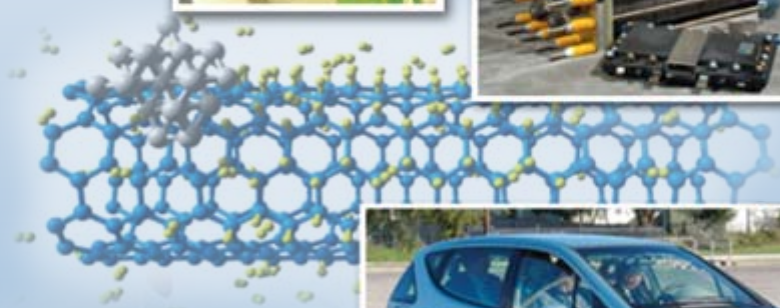
Potential

- Commercially viable hydrogen and fuel cell systems by 2015

NREL Research Thrusts

- Hydrogen production, delivery, storage and manufacturing
- Fuel cells
- Safety, codes, and standards
- H_2-to-Wind – NREL/Xcel Project
  - Maximize wind energy by reducing uncertainty and variability
  - Hydrogen produced through electrolysis





Source: DOE, NREL, 9/07

Geothermal

Today's Status:

- 2,800 MWe installed, 500 MWe new contracts, 3000 MWe under development
- Cost 5-8¢/kWh with no PTC
- Capacity factor typically > 90%, base load power

DOE Cost Goals:

- <5¢/kWh, for typical hydrothermal sites
- 5¢/kWh, for enhanced geothermal systems with mature technology

Long Term Potential:

- Recent MIT Analysis shows potential for 100,000 MW installed Enhanced Geothermal Power systems by 2050, cost-competitive with coal-powered generation

NREL Research Thrusts:

- Analysis to define the technology path to commercialization of Enhanced Geothermal Systems
- Low temperature conversion cycles
- Better performing, lower cost components
- Innovative materials

Source: DOE, NREL, 9/07

Biopower

Biopower status

- 2006 Capacity – 10.5 GWe
  - 5 GW Pulp and Paper
  - 2 GW Dedicated Biomass
  - 3 GW MSW and Landfill Gas
  - 0.5 GW Cofiring
- 2004 Generation – 68.5 TWh
- Cost – 0.08 – 0.10 USD/kWh

Potential

- Cost – 0.04-0.06 USD kWh (integrated gasification combined cycle)
- 2030 – 160 TWh (net electricity exported to grid from integrated 60 billion gal/yr biorefinery industry)

Plug-In Hybrid Electric Vehicles (PHEV)

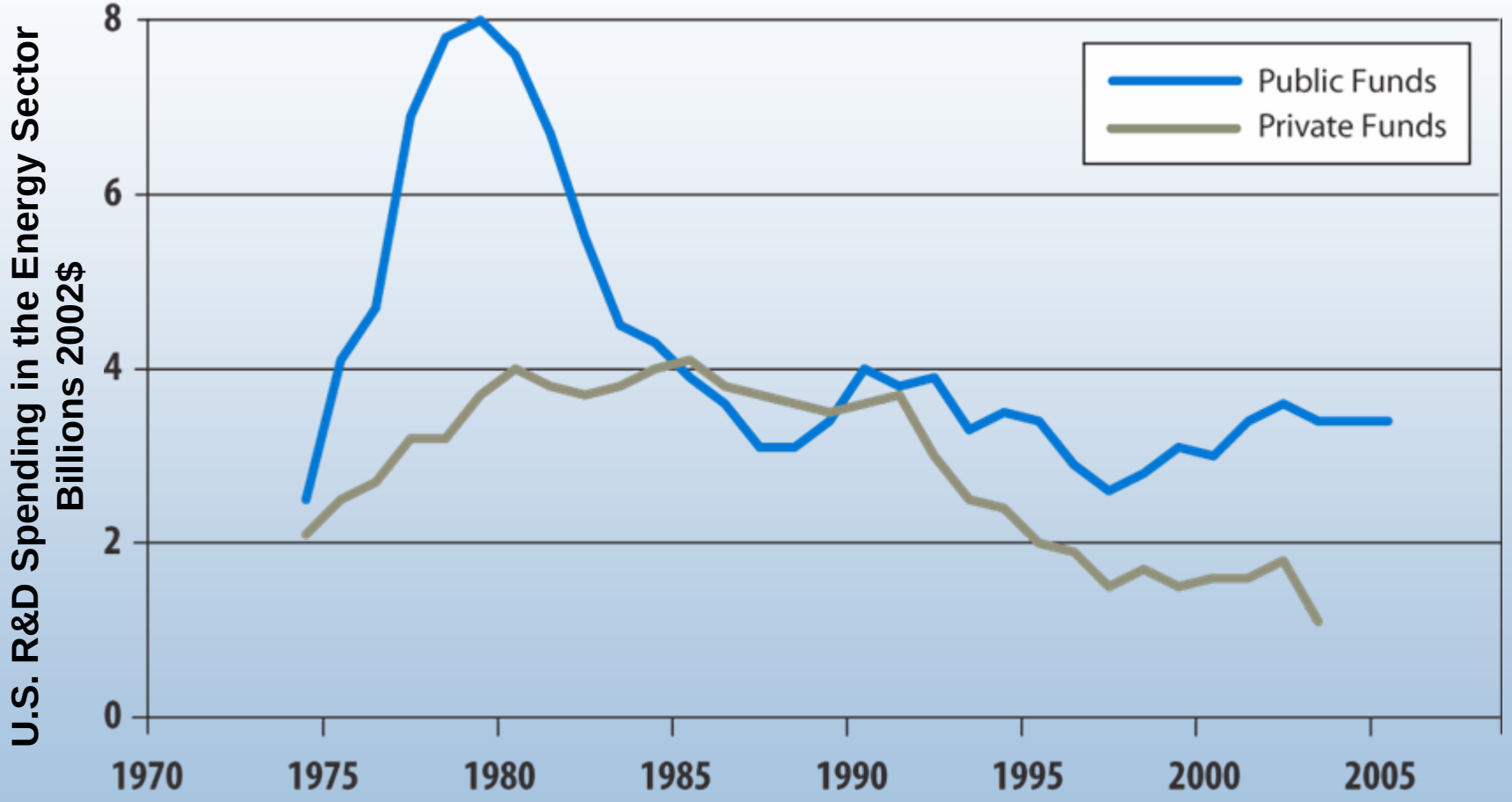
Status:
- PHEV-only conversion vehicles available
- OEMS building prototypes
- NREL PHEV Test Bed

NREL Research Thrusts
- Energy storage
- Advanced power electronics
- Vehicle ancillary loads reduction
- Vehicle thermal management
- Utility interconnection
- Vehicle-to-grid

Key Challenges
- Energy storage – life and cost
- Utility impacts
- Vehicle cost
- Recharging locations
- Tailpipe emissions/cold starts
- Cabin heating/cooling
- ~33% put cars in garage

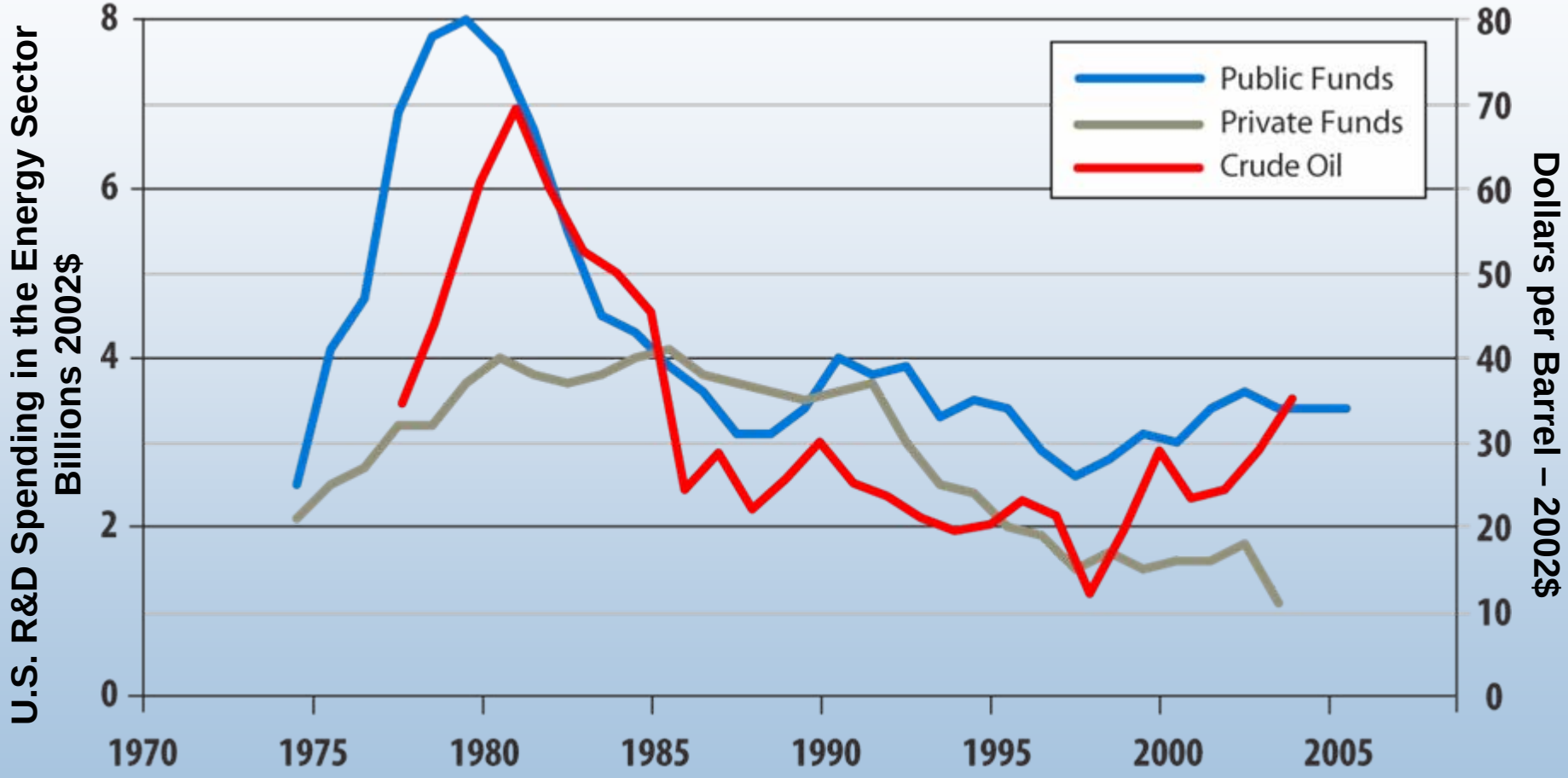
Must policy measures include a correspondingly aggressive investment in technology innovation and cost reduction?

Declining Energy R&D Investments…



Source: Daniel Kammen, Gregory Nemet *Reversing the Incredible, Shrinking Energy R&D Budget* http://rael.berkeley.edu/files/2005/Kammen-Nemet-ShrinkingRD-2005.pdf
Table 10.3, Edition 25, *Transportation Energy Data Book* http://cta.ornl.gov/data/chapter10.shtml

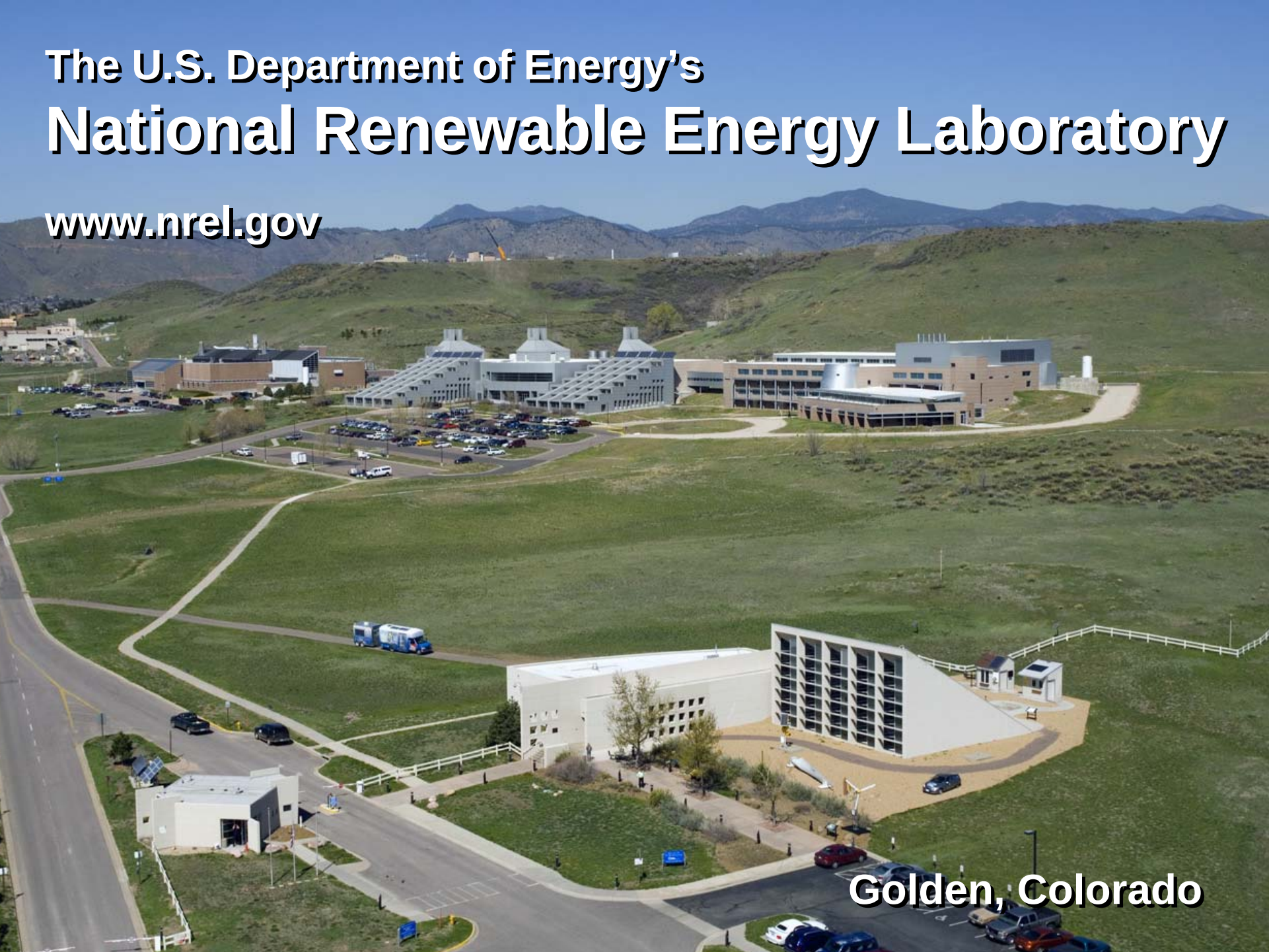
Declining Energy R&D Investments… Reflect World Oil Price Movement



Source: Daniel Kammen, Gregory Nemet *Reversing the Incredible, Shrinking Energy R&D Budget* http://rael.berkeley.edu/files/2005/Kammen-Nemet-ShrinkingRD-2005.pdf
Table 10.3, Edition 25, *Transportation Energy Data Book* http://cta.ornl.gov/data/chapter10.shtml

Achieving the Right Balance:
Technology Investment Pathways

Source: NREL 2007


The U.S. Department of Energy's
National Renewable Energy Laboratory
www.nrel.gov
Golden, Colorado